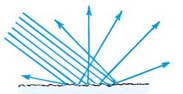
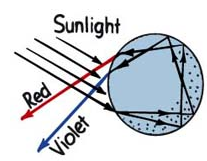
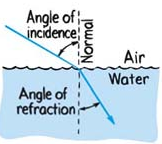
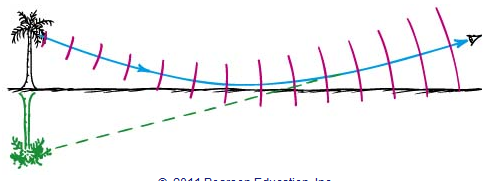
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| --- | --- |
| |  | | --- | | **CHAPTER  28 Reflection and Refraction**  Lenses are not going to be tested in detail  In this chapter, ignore light absorbed & converted to heat energy & concentrate on the light that continues to be light after it meets a surface | |
|  |
| |  |  |  | | --- | --- | --- | | Reflection |  | The return of light rays from a surface. | |  | | | | Refraction |  | The bending of an oblique ray of light when it passes from one transparent medium to another. | |  | | | | Fermat’s principle of least time |  | Light takes the path that requires the least time when it goes from one place to another. | |  | | | | Law of reflection |  | The angle of reflection equals the angle of incidence. | |  | | | | Diffuse reflection |  | Reflection in irregular directions from an irregular surface. | |  | | | | Critical angle |  | The minimum angle of incidence inside a medium at which a light ray is totally reflected. | |  | | | | Total internal reflection |  | The total reflection of light traveling within a denser medium when it strikes the boundary with a less dense medium at an angle greater than the critical angle. | |  | | | | Converging lens |  | A lens that is thicker in the middle than at the edges and that refracts parallel rays to a focus. | |  | | | | Diverging lens |  | A lens that is thinner in the middle than at the edges, causing parallel rays to diverge as if from a point. | |  | | | | Virtual image |  | An image formed by light rays that do not converge at the location of the image. | |  | | | | Real image |  | An image formed by light rays that converge at the location of the image. A real image, unlike a virtual image, can be displayed on a screen. | |  | | | | Aberration |  | Distortion in an image produced by a lens, which to some degree is present in all optical systems. | |
| **Reflection** |

* **Light interacts with atoms as sound interacts with tuning forks.**
* **Principle of Least Time ;** light will take the most efficient path and travel in a straight lineif there is nothing to obstruct the passage of light between the 2 points
* [**Fermat’s principle of least time**](javascript:;). Fermat’s idea was this: Out of all possible paths that light might travel to get from one point to another, it travels the path that requires the shortest time.

**Law of Reflection**

* different points on the mirror vary as to how long it takes the light to travel
* How can we find the exact point on the mirror for which the time is shortest?.
* Construct, on the opposite side of the mirror, an artificial point, B′, which is the same distance “through” and below the mirror as the point B is above the mirror. Inspection will show that the distance from C to B equals the distance from C to B′. We see that the length of the path from A to B′ through C is equal to the length of the path from A to B bouncing off point C along the way.
* Further inspection and a little geometrical reasoning will show that the angle of incident light from A to C is equal to the angle of reflection from C to B. This is the [**law of reflection**](javascript:;), and it holds for all angles
* **The angle of incidence equals the angle of reflection.**
* The law of reflection is illustrated with arrows representing light rays
* it is customary to measure angles of incident and reflected rays from the reflecting surface- from a line perpendicular to plane of reflecting surface.
* This imaginary line is called the normal. The incident ray, the normal, and the reflected ray all lie in the same plane.

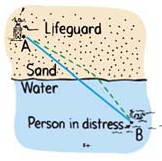
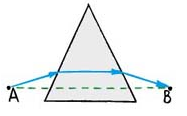
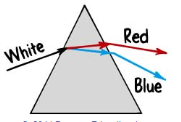
Plane Mirrors

* **A virtual image is formed behind the mirror and is located at the position where the extended reflected rays (dashed lines) converge.**   
  When rays encounter the mirror, they are reflected at angles equal to their angles of incidence.
* An observer sees an image of flame at this point but the rays do not actually come from this point, so the image is called a **virtual image**.
* The image is as far behind the mirror as he is in front and is the same size
* Has the same color of clothing—evidence that light doesn’t change frequency upon reflection.
* The virtual image formed by a convex mirror (a mirror that curves outward) is smaller and closer to the mirror than the object.
* If object is close to a concave mirror (a mirror that curves inward like a “cave”), the virtual image is larger & farther away than the object.
* A curved mirror behaves as a succession of flat mirrors, each at a slightly different angular orientation from the one
* Only part of the light that strikes a surface is reflected. On a surface of clear glass, only about 4% is reflected from each surface. On a clean and polished aluminum or silver surface, however, about 90% of incident light is reflected.
* **Although each ray obeys the law of reflection, the many different surface angles that light rays encounter in striking a rough surface cause reflection in many directions.**
* **Diffuse Reflection-** light is incident on a rough surface and is reflected in many directions
* If the surface is so smooth there is very little diffuse reflection, and the surface is said to be polished.
*  A surface, may be polished for radiation of a long wavelength but not polished for light of a short wavelength.
* **An open-mesh parabolic dish is a diffuse reflector for short-wavelength light but a polished reflector for long-wavelength radio waves.**
* Rays of light that strike this page encounter millions of tiny flat surfaces facing in all directions. The incident light therefore is reflected in all directions enabling us to see objects from any direction or position
  + ghost image that occurs on TV where signal bounces off buildings and other obstructions

**Refraction****-**

* **process where** light bends in passing obliquely from one medium to another

**Cause of Refraction**

* refraction is a consequence of light having different average speeds in different media.
* Refraction occurs when the average speed of light changes in going from one transparent medium to another.
* The direction of the light waves changes when one part of each wave slows down before the other part.
* A ray of light bends and takes a longer path when it encounters glass or water at an oblique angle but the longer path taken is nonetheless the path requiring the least time.
* A lifeguard at a beach spots a person in distress in the water.
* You can run faster than you can swim. Should you travel in a straight line to get to B?
* The path of shortest time is shown by the dashed-line path, which clearly is not the path of the shortest distance.
* The amount of bending at the shoreline depends on how much faster you can run than swim.
* The situation is similar for a ray of light incident upon a body of water
* . The angle of incidence is larger than the angle of refraction by an amount that depends on the relative speeds of light in air and in water
* Refraction through glass.
* Example- **the prism** has opposite faces of the glass that are not parallel
* Light that goes through will not follow a straight-line path b/c
* light will follow the solid line—and pass through a thinner section of the glass the prism and
* one might think that the light should take a path closer to the upper vertex of seek the minimum thickness of glass. But if it did, the extra distance through the air would result in an overall longer time of travel. The path followed is the path of least time.

A curved prism-

* A converging lens
* The curve decreases thickness of the glass correctly to compensate for the extra distances light travels to points higher on the surface.
* Earth’s atmosphere is thin at the top and dense at the bottom. Since the density changes gradually, the light path bends gradually to produce a curved path. this path of least time provides us with a slightly longer period of daylight each day. When the Sun (or Moon) is near the horizon, they appear to be higher in the sky b/c the rays are bent more - causing the Sun to appear elliptical .
* **Mirage**
* Viewing an object over hot pavement, we see a wavy, shimmering effect due to the various least-time paths of light as it passes through varying temperatures and therefore varying densities of air.
* The twinkling of stars results from similar phenomena in the sky
* Light from the sky picks up speed in the air near the ground because that air is warmer and less dense than the air above. When the light grazes the surface and bends upward, the observer sees a mirage.
* Light travels faster through the thinner hot air than through the denser cool air above.
* A mirage is formed by real light and can be photographed
* A mirage. The apparent wetness of the road is not reflection of the sky by water but, rather, refraction of sky light through the warmer and less-dense air near the road surface.
* If the speed of light were the same in air of various temperatures and densities, would there still be slightly longer daytimes, twinkling stars at night, mirages, and slightly squashed Suns at sunset? NO

**A wave explanation of a mirage.**

* **Wave fronts of light travel faster in the hot air near the ground and bend upward.**
* ***When light slows down in going from one medium to another, such as going from air to water, it refracts toward the normal.***
* ***When it speeds up in traveling from one medium to another, such as going from water to air, it refracts away from the normal.***

**A light ray is always at right angles to its wave front**.

* Because of refraction, submerged objects appear to be magnified.

**Dispersion**

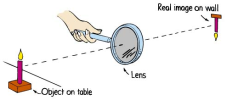
* Dispersion by a prism makes the components of white light visible
* The speed of light in a transparent medium depends on its frequency.
* Light waves with colors between red and violet travel at their own intermediate speeds.
* Because different frequencies of light travel at different speeds in transparent materials, they refract by different amounts.
* This separation of light into colors arranged according to frequency is called dispersion.
* **Rainbows are** llustrations of dispersion
* to be seen, the Sun must be shining in one part of the sky and water drops in a cloud or in falling rain must be present in the opposite part of the sky.
* All rainbows would be completely round if the ground were not in the way.
* A ray of sunlight enters a drop near its top surface some of the light iis reflected & the remainder is refracted into water.
* red angle is between a beam of sunlight and the light sent back by a drop is 42°.
* **Sunlight incident on two sample raindrops, as shown, emerges from them as dispersed light. The observer sees the red light from the upper drop and the violet light from the lower drop. Millions of drops produce the whole spectrum of visible light.**
* Your cone of vision that intersects the cloud of drops that creates your rainbow is different from that of a person next to you.
* Everybody sees his or her own personal rainbow.
* A rainbow always faces you squarely. When you move, your rainbow moves with you. Two refractions and a reflection in water droplets produce light at all angles up to about 42°, with the intensity concentrated where we see the rainbow at 40° to 42°. No light emerges from the water droplet at angles greater than 42° unless it undergoes two or more reflections inside the drop. So the sky is brighter inside the rainbow than outside it. Notice the weak secondary rainbow to the right of the primary.

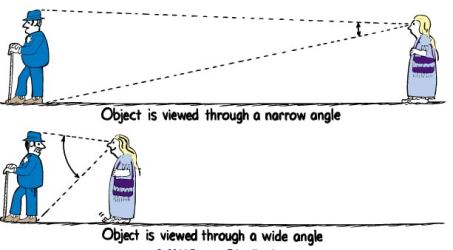
**Total Internal Reflection**

* **Light emitted in the water is partly refracted and partly reflected at the surface. The dashes show the direction of light and the length of the arrows indicates the proportions refracted and reflected. Beyond the critical angle, the beam is totally internally reflected.**
* At a certain angle, called the critical angle, the beam no longer emerges into the air above the surface.
* The [**critical angle**](javascript:;) is the minimum angle of incidence inside a medium at which a light ray is totally reflected.
* When the flashlight is tipped beyond the critical angle (48° from the normal for water), you’ll notice that all the light is reflected back into the tub. This is [**total internal reflection**](javascript:;).
* The light striking the air–water surface obeys the law of reflection: The angle of incidence is equal to the angle of reflection. The only light emerging from the surface of the water is that which is diffusely reflected from the bottom of the bathtub.
* The critical angle for a diamond is about 24.5°, smaller than for any other known substance.

**Fiber Optics** light is “piped” by a succession of total internal reflections until it emerges at the top ends.

* Optical fibers are important in communications because they carry thousands of simultaneous telephone messages.
* Unlike electricity, light is indifferent to temperature and fluctuations in surrounding magnetic fields, and so the signal is clearer.

**Lenses**

* A lens may be thought of as a set of blocks and prisms
* [**diverging lens**](javascript:;)**-**  middle is thinner than the edges, and it diverges the light.
* the greatest deviation of rays occurs at the outermost prisms, for they have the greatest angle between the two refracting surfaces.
* No deviation occurs exactly in the middle, for in that region the glass faces are parallel to each other.
* Wave fronts travel more slowly in glass than in air. (a) The waves are retarded more through the center of the lens, and convergence results. (b) The waves are slowed more at the edges, and divergence results.
* The principal axis of a lens is the line joining the centers of curvatures of its surfaces.
* The focal point is the point to which a beam of parallel light, parallel to the principal axis, converges.
* Because a lens has two surfaces, it has two focal points and two focal planes.
* When the lens of a camera is set for distant objects, the film is in the focal plane behind the lens in the camera.
* The first cameras had no lenses and admitted light through a small pinhole.
* Long exposure times were required because of the small amount of light admitted by the pinhole.
* A somewhat larger hole would admit more light, but overlapping rays would produce a blurry image.
* Too large a hole would allow too much overlapping and no image would be discernible.
* a converging lens converges light onto the screen without the unwanted overlapping of rays
* The simplest use of a converging lens is a magnifying glass.
* W/unaided vision, a far-away object is seen through a relatively narrow angle of view and a close object is seen through a wider angle
* When close to the object, the magnifying glass gives you a clear image that would be blurry otherwise.
* a converging lens provides an enlarged, right-side-up image only when the object is inside the focal point.
* **When an object is near a converging lens (inside its focal point f), the lens acts as a magnifying glass to produce a virtual image.**
* **The image appears larger and farther from the lens than the object.**
* **When an object is far from a converging lens (beyond its focal point), a real upside-down image is formed.**
* When the object is far away enough to be outside the focal point of a converging lens, a [**real image**](javascript:;) is formed instead of a virtual image.
* **diverging lens forms a virtual, right-side-up image of Jamie and his cat**
* .A diverging lens used alone produces a reduced virtual image. It makes no difference how far or how near the object is.
* When a diverging lens is used alone, the image is always virtual, right-side up, and smaller than the object.
* **Lens Defects** - No lens provides a perfect image. A distortion in an image is called an [**aberration**](javascript:;).
* aberrations can be minimized using compound lenses, each consisting of several simple lenses, instead of single lenses.
* Spherical aberration results from light that passes through the edges of a lens focusing at a slightly different place from where light passing near the center of the lens focuses
* Chromatic aberration is the result of light of different colors having different speeds and hence different refractions in the lens b/c different colors of light do not come to focus in the same place.
* Vision is sharpest when the pupil is smallest because light then passes through only the central part of the eye’s lens, where spherical and chromatic aberrations are minimal.
* You see better in bright light because in such light your pupils are smaller.
* Astigmatism of the eye is a defect that results when the cornea is curved more in one direction than the other